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PROJECT EXPLORER, GAS # 007
MARSHALL AMATEUR RADIO CLUB EXPERIMENT (MARCE)

STS-61C, COLUMBIA FLIGHT
FINAL REPORT

by
EDWARD F. STLUKA, W4QAU
MARCE PRINCIPAL INVESTIGATOR

ABSTRACT

This paper reviews the performance of the MARCE. The responses, from the World Wide Amateur Radio Ground Stations, who received the Columbia to Earth direct radio downlinks, are discussed. Likewise, the MARCE radio relay link from Columbia through the AMSAT OSCAR AO-10 satellite to Earth is reviewed.

INTRODUCTION

GAS #007 was sponsored by Mr. Edward O. Buckbee, the Director of the Alabama Space and Rocket Center, Huntsville, AL, in cooperation with the Alabama Section of the American Institute of Aeronautics and Astronautics. Dr. Konrad Dannenberg, Project Explorer Manager, performed a cohesive and superb management task of keeping the Project Explorer team together and interfacing with the Get Away Special Officials at the Goddard Space Flight Center. Project Explorer was planned to allow high school science students to fly their own experiments on the Space Shuttle.

The University of Alabama (UA) Huntsville, UA Tuscaloosa, Auburn University and The Alabana A & M University counselors selected the student proposals, in 1978.

Three student experimenters maintained their interest and persevered. They finally witnessed their experiments: Solidification of Alloys; Plant Physiology; and Crystal Growth complete the long sought flight.

The Marshall Space Flight Center Amateur Radio Club (MARC) was requested to integrate the payload and provide the power, control, measuring and data systems. The MARCE design, development, testing, coordination and flight history are described in the 1984 and 1985 GAS Experimenter's Symposium Proceedings.

The final success of the MARCE primary objective was dependent on volunteer radio amateur operators, around the world, who would receive the 435.033 MHz transmitted "Voice Message", from Columbia and relay the data to the MARC, in Huntsville, Alabama.

The secondary objective of relaying MARCE transmissions from Columbia through the AMSAT (Radio Amateur Satellite Corporation) OSCAR (Obriting Satellite Carrying Amateur Radio) AO-10 Satellite to Earth on 145.972 MHz was realized when Joel Chalmers, KG6DX in Guam, recorded a readable voice message. This amateur radio experiment objective was considered remotely improbable by the experts because of the low 5 watt transmitter power and related link parameters.

MARCE could not have been successfully completed without the positive and excellent support from those willing to provide hardware, namely: 1. Motorola, Fort Lauderdale, FL - 5 watt FM transmitter and GSE receiver; 2. National Semiconductor Corp., Interep Associates, Huntsville, AL - two sets of data system modules; 3. Zero Corp., Monson, Mass - Electronic Support Assembly Enclosure; 4. Midwest Components Inc., Muskegon, MI - Thermal Sensitive Switches; 5. ICOM America Inc., Bellevue, WA - IC-271A and IC-471A, OSCAR Ground Station Transceivers; 6. KLM & Mirage, Gilroy, CA - CA-2M-22C and 435-18C OSCAR Antennas; 7. Trio-Kenwood Communications, Compton, CA - TS-430S Transceiver, power supply and speaker, TL-922A Linear Amplifier; 8. University of Alabama, Huntsville Environmental Lab.- Guy Smith, as head of the Lab. and Principal Investigator of the Plant Physiology experiment, provided space for the GAS #007 fabrication, assembly and testing, for both the STS-41G and the STS-61C flights. The UAH also provided machine shop and related work. Guy performed a vital and major part of the detail assembly and fastener selection and provided standard laboratory test equipment.

MARCE was completed, over an eight year period, by volunteers and support from the electronics industry, The University of Alabama, Huntsville, amateur radio groups and surplus space hardware. The first GAS #007 flight, on STS-41G, October 1984, had a 57 degree inclination, had about four months of advanced coordination and publicity and was launched on Challenger as planned, however, power was never applied because of an operational error. STS-61C planning data was not available until about four weeks prior to the December 18, 1985 first scheduled launch date.

AMSAT's telemail and Amateur Radio International Nets plus the American Radio Relay League's (ARRL) W1AW bulletins were the primary pre-flight data desimination methods. The record six delays taxed the Orbiter mission operations and AO-10 timeline updating, especially to the remote areas. With the low 28.5 degree inclination and the many delays, the amateur radio coverage was uncertain. Without AMSAT and the ARRL's W1AW updates, the MARCE would have not been successful.

The bulk of the cassettes and transcriptions were sent to N6ARE, Jullian Macassey, Pasadena, CA., (AMSAT Vice President of Operations) per the AMSAT Report. Julian agreed to be the focal point for receiving and forwarding the MARCE data to MARC. A few cassettes were sent direct to MARC, per earlier MARC publicity.

FLIGHT CONFIGURATION

GAS #007 was mounted in the forward position #4 on the GAS Bridge, to maximize the distance from the aft bulkhead. The GAS Bridge was designed by the Teledyne Brown Engineering Co., Huntsville, AL. See Figure 1. The MARCE antenna, designed by Reggie Inman, was mounted so that the half-wave dipole rods were pointed in the X or flight direction, to reduce RF reflection on the cargo bay's aft bulkhead. Figure 2 shows the student experiment layout and Figure 3 is the MARCE side.

The experiment package weighted 170 of the alloted 200 pounds. The SRB Eagle Picher 50 amp hour battery supplied primary power. The 5 watt FM transmitter was turned on at the start of each minute, during each eight hour downlink.

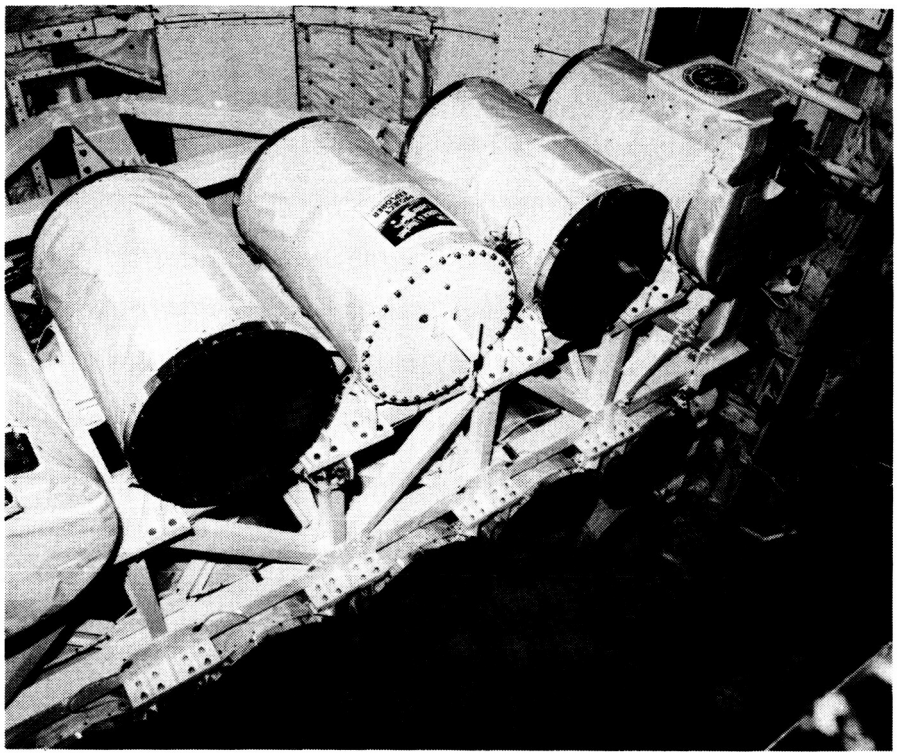

FIGURE 1

STS-61C COLUMBIA
LAUNCHED JANUARY 12, 1986
GAS # 007 PROJECT EXPLORER

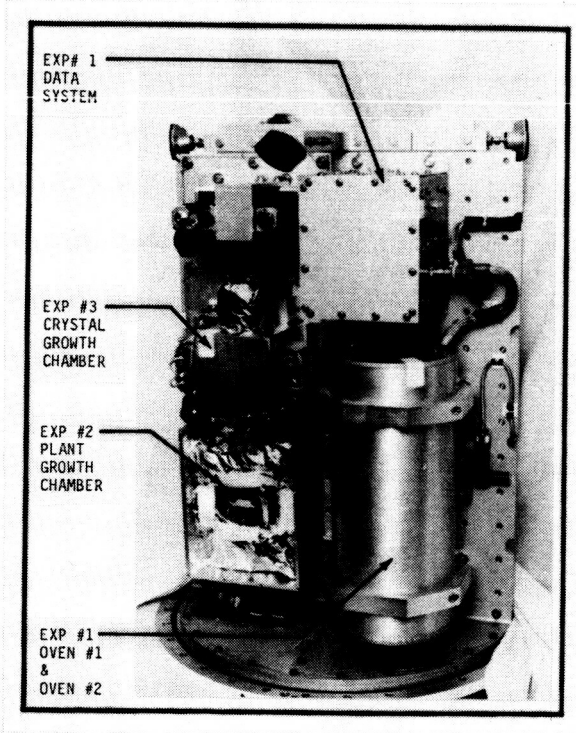

FIGURE 2

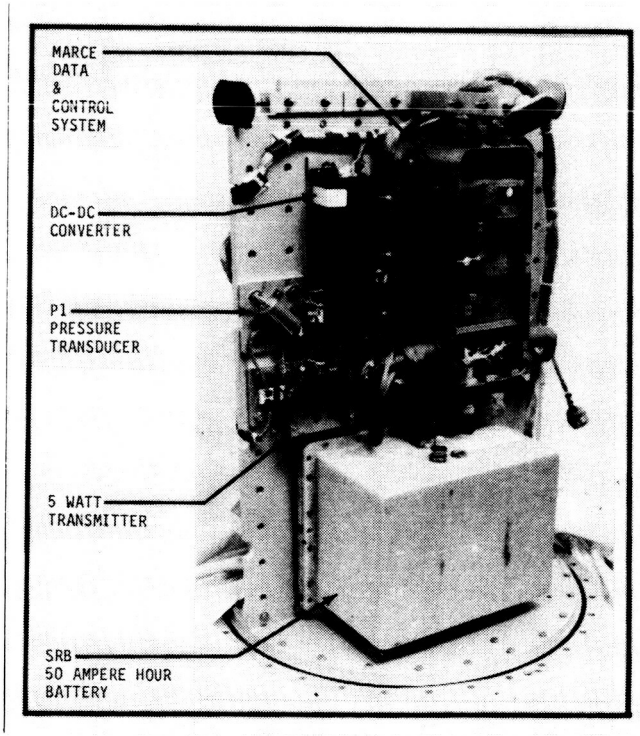

FIGURE 3

The STS-41G control system, designed by Art Davis, WB4KKA and Chris Rupp, W4HIY was configured for one transmission every 4 minutes, to conserve power. The 10 dB attenuator, required on the STS-41G mission, was not required on this mission.

The data system modules included the Digitalker™ and the NSC 800 microprocessor. The data system memory stored the voice message data every 10 minutes, through out the powered mission. The direct downlink data which was transmitted at the start of each minute, during each eight hour downlink, provided a vital set of data, that would not be available without world wide amateur radio operator support.

A total of 1,440 transmissions were programmed, for the three 8 hour downlinks. 486 messages have been received to date, which is 33.7%, of the 24 hour transmitter operation.

110 hours of GAS #007 operation were recorded in the MARCE memory, giving 660 data messages stored in memory. The one minute messages provided valuable transient data values, allowing more critical experiment performance evaluation to be conducted. The pre-prepared GAS #007 power profiles allowed a comparison of design to flight operations. The results were excellent and exciting, when the comparison was made in near real time.

PRE-FLIGHT COORDINATION

The three in-space emission notifications were sent to the FCC and approval was received. Likewise the Cape Canaveral approval for pre-flight emission tests was received. Two SRB batteries were activated and load tested. Leigh Du Pre', WB4WCX carried the GAS #007 flight package to Cape Canaveral, FL and with Guy Smith, they performed the pre-flight final assembly and tests, for the flight GAS container integration.

Gil Carman, WA5NOM, provided the STS-61C, Columbia timelines and ground tracks for downlinks 1, 2, and 3 and OSCAR AO-10 timelines, for MARCE to OSCAR AO-10 relay opportunities. AMSAT distributed this data along with AMSAT's AO-10 tracking data.

Vern (Rip) Riportella, WA2LQQ, president of AMSAT and editor of the Amateur Satellite Report (ASR), informed the world wide AMSAT community about MARCE via ASR, Telemail and the AMSAT Radio Nets.

Bernie Glassmier, W9KDR, W1AW manager, sent daily bulletins world wide, from the ARRL's powerful radio station in Newington, Conn..

FLIGHT SUMMARY AND SUPPORT ACTIVITIES

STS-61C, with Orbiter Columbia, was the 24th Space Shuttle flight. The crew: Robert L. Gibson, Cmdr.; Charles F. Bolden, Pilot; Franklin Chang-Diez, Mission Specialist (MS); Steven A Hawley, MS; George D. Nelson, MS; Robert Cenkter, Payload Specialist (PS)-RCA; Bill Nelson, PS-U.S. Congressman.

Launch occurred on January 12, 1986, at 11:55 UTC, from The Kennedy Space Center, FL. The flight completed 6 days, 2 hours and 4 minutes, with the landing at Edwards AFB, CA, on January 18, 1986, at 12:59 UTC. The launch was delayed six times and the landing attempt waved off three times.

On January 12, 1986, the MARC conducted an STS-61C and MARCE commemorative and was manned to receive radio relays of the first downlink. The first transmission started east of Ascension Island, at the end of orbit #8, at 2345 GMT. Jim Martin, K5QNI, GSFC, coordinated the NASA Ground Station amateur radio operations with Ascension and Guam Islands.

The first report received was from Gil Carman, WA5NOM, Houston, TX. Gil heard the MARCE relay through AO-10, about 30 minutes after GAS #007 turn-on. The signal was too weak to read the voice message, but the frequency, the 30 second transmissions, the spin modulation and the doppler were sufficient to confirm power-on.

The second confirmation received was from V. Rip Riportella, WA2LQQ, who relayed the 00121, 00122 and 00123 hours, voice messages received by Junior De Castro, PY2BJO, in Sao Paulo, Brazil. Junior provided the first real data revealing that the battery was healthy, the 8 status conditions were proper, as were the temperatures and the pressure. Junior provided subsequent reports by telephone, whereby the data was re-recorded on our cassette.

The downlinks 1, 2 and 3 tracking timelines were used for correlating Columbia's location and MARCE transmission times. Many of the ground stations were equipped with computers. This allowed independent tracking of Columbia and AO-10, since the Keplerian elements were available for both. The missing link was the MARCE transmitter turn-on times. This was provided through AMSAT, W1AW and other amateur radio means.

The three downlinks occurred as planned. When the STS-61C mission was cut short due to weather, GAS #007 was powered down at the end of the third day, with the other GAS payloads. However, when weather forced the first of three wave-offs, a request to power-up GAS #007 was authorized for a fourth unscheduled eight hour downlink. At the end of the fourth day, GAS #007 was again powered down, for an intended landing the next morning. When weather again extended the mission, a fifth downlink was initiated. Frantic coordination was attempted to inform as many world wide amateur radio operators as possible. The fourth downlink could not have been received, but this was not known until it was learned from the MARCE post flight memory data dump that the transmitter had not been turned on. The memory data showed that GCD relay B was not actuated, for the fourth downlink but was for the fifth downlink. This was easily varifiable by studying the I1 current reading. The data provided an excellent signature of actual operation.

On April 17, 1986, a very valuable mini cassete tape was received from JA8BSK/Kohji Yokono in Hokkaido Japan. It provided the only messages received, to date, from the fifth downlink.

FLIGHT DATA

The "POST FLIGHT DATA ANALYSIS" of the on-board MARCE memory and data system is presented in a separate paper by Charles C. Rupp, W4HIY. Chris did it all! He designed the data system, selected the components, built the pc boards from masking to soldering and testing, did all of the software and debugging. And he stuck with it during these many years. That type of dedication and individual expertise is seen in the many other persons involved in this project,

and traceable to the many amateur radio operators who gave their time, postage, cassette tapes, etc. to make MARCE a SUPER success.

The "DIRECT DOWNLINK GROUND STATION RESULTS" are provided in Table 1, which lists the world wide Amateur station locations and the MARCE message data gathering details, for all direct downlink messages received. A summary of the direct downlink results is provided at the end of Table 1.

The data analysis revealed large variations in temperature, with the exception of T1, mounted on the outside of Experiment 1, Oven 1 and T2, mounted on the outside of Oven 2. T1 and T2 were designed to measure and react (control) if either oven developed an over temperature condition, which never occured. T3 through T6 revealed the colder than expected temperatures. The low temperatures, at the start of Downlinks 2 and 3 resulted from low power consumption after each downlink. T3 shows warmer temperatures because of Experiment 2 heater. T4 shows a colder than expected condition - Experiment 3 heater batteries expired. T5 measured the canister internal ambient temperature. T6 was located in the center of the SRB battery. V1 and I1 measured the SRB battery voltage and current. Both were nominal, even with the temperature far below the expected low of -5° C. P1, the cansister pressure, varied with the temperature, as expected. The measurements were taken directly from the data provided by those listed in Table 1.

The response from those listed in Table 1 was beyond our wildest expectations. The data is extra special, as it filled the gaps, between the 10 minute on-board data storage points, in significant numbers. The annotations on the data cassettes and letters received were very interesting and supportive of MARCE, the Space Shuttle Program, the Get Away Special Program and Amateur Radio.

The many hours of tracking, listening and planning, by the large group of ground station operators is evident by the Table 1 analysis. Those who attempted to receive the AO-10 relays spent many hours with disappointing results. The many hours of cassette recordings is factual evidence. Many AO-10 relay signals are recorded, with the spin modulation very evident, but no voice messages because of the very weak signals. The 30 and 45 second transmissions are also evident.

A special commemorative certificate will be sent to all those participating in this very successful space experimentation venture.

STUDENT EXPERIMENT RESULTS SUMMARY

Experiment 1, Solidification of Alloys, Ovens 1 and 2 performed as planned. A thermocouple in each oven malfunctioned. Redundant thermocouples gave the temperature readings needed.

Experiment 2, Plant Physiology, did not have the 120 hours desired. Less than 70 hours were available due to the shortened mission. Also, the growth chamber was colder than planned. A few centimeters of root growth did occur, so a limited success was realized.

Experiment 3, Crystal Growth, likewise had limited success. The heater batteries expired, resulting in a colder environment than planned. A few millimeters of crystals grew. These short crystals made it extremely difficult to make measurements. Also, the solution froze and thawed during the mission. The effects are being studied.

MARCE DIRECT DOWNLINK VOICE MESSAGES

CALL	NAME	PLACE	# OF VOICE MESSAGES
CE3BCF	JAIME G. COSTABAL	SANTIAGO, CHILE	6
CE3KB	RAMON C. JIMENEZ	SANTIAGO, CHILE	14
CE3XK	RENATO C. REEVES	SANTIAGO, CHILE	31
F1CDC	CLAUDE CARLIERE	L'UNION, FRANCE	5
JA2BGX	KAZUYUKI OKUMURA	SHIZUOKA, JAPAN	35
JA2GSD	KIICH YAMAGUCHI	SHIZUKA-KEN, JAPAN	30
JA2NCF	AIJI KAWAI	SHIZUOKA, JAPAN	28
JA3CF	YOSHI HIRO	WAKAYAMA, JAPAN	4
JA3XJK	TERUO KURODA	JYOUD KYOTO, JAPAN	12
JA8BSK	KOHJI YOKONO	HOKKAIDO, JAPAN	7
JA8PL	M. SATO	HOKKAIDO, JAPAN	2
JE3MXU	HIRO	JAPAN	4
JH1RNZ	ISAO NAKASHIMA, MD	KANAGAWA, JAPAN	28
JH2DCW	SHINNOSUKE YAMADA	SHIZUOKA, JAPAN	9
JH3FDA		JAPAN	17
JH6EGU/2	MICHIYASU SAKAIDA, MD	TOKIWA, JAPAN	19
JH7CKF	HAJIME JUKUDA	KWATE, JAPAN	8
JI1VYH	YASUO NAGAI	TOKYO, JAPAN	NO TIMES
JR1RBR	KEIJI IMAI	TOKYO, JAPAN	5
=====	MINORU OHMINE	OKINAWA, JAPAN	5
KG6DX	JOEL CHALMERS	LATTE HEIGHTS, GUAM, IS	70
PY2BJO	JUNIOR T. DE CASTRO	SAO PAULO, BRAZIL	47
VK5AGR	G. R. RADCLIFF	CLARENCE PEAK, SOUTH AUSTRALIA	7
WH6AMX	RICK G. DITTMER	HONOLULU, HAWAII	10
ZD8LM	LEE MC LAMB	ASCENSION, IS	44
ZL1AOX	IAN ASHLEY	AUCKLAND, NEW ZEALAND	14
ZL1PK	PHIL KING	ROTORAU, NEW ZEALAND	1
ZL1TEE	R. RALPH CARTER	AUCKLAND, NEW ZEALAND	2
ZS6AKV	J. VAN DE GROENANDALL	RYNFIELD, SOUTH AFRICA	8
ZS6BMN	JAN HATINGH	VERWOERDBURG, SOUTH AFRICA	6
5Z4EG	ANTHONY G. HIGBY	NIROBIE, KENYA	3
5Z4RG	ALAN HORNE	NIROBIE, KENYA	6

SUMMARY OF MARCE VOICE MESSAGES

	%	No.
JAPAN	44	213
ALL OTHERS	56	273
TOTAL		486

SUMMARY OF GROUNDSTATIONS

	No.
JAPAN	16
SO. AFRICA	2
ASCENSION, IS	1
AUSTRALIA	1
BRAZIL	1
CHILE	3
FRANCE	1
GUAM, IS	1
HAWAII	1
KENYA	2
NEW ZEALAND	3
TOTAL	32

TABLE 1